

16.5L: Late-News Paper: A New Design to Improve Performance and Simplify the Manufacturing Process of High-Quality MVA TFT-LCD Panels

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Abstract

An MVA(Multi-domain Vertical Alignment)- TFT LCD panel has been redesigned to improve optical performances and to reduce process step. The optical transmittance was improved by newly introduced protrusion wings to remove undesirable disclination lines caused by edge field effect of the pixel. Also, an aperture of the black matrix on the CF substrate was extended to include whole ITO pixel since the operating mode of the liquid crystal is Normally-Black mode. The protrusions on the TFT substrate was replaced to patterned ITO slit. This results in the contrast ratio improvement, and simplifies the manufacturing process.

Introduction

Large-size monitors for desktop have begun to replace CRTs with LCDs that have the advantage of saving space and consuming less power. But there are many problems that must be improved such as viewing angle, response speed and so on. In 1997, we developed an MVA(Multi-domain Vertical Alignment)-LCD in which LC domains were divided into four different tilted directions and LCs were operated by Normally-Black mode with vertical alignment at the off state(1,2). The MVA-LCD realizes super high quality display that is able to represent very wide viewing angles of more than 160 degrees both for vertical and horizontal directions with very high contrast ratio of 300 : 1. Also due to the nature of the vertical alignment LCDs, the response speed is very fast of 25ms (on-off), and the rubbing step has been eliminated from the LC alignment process.

We have been manufacturing MVA-TFT LCDs since Oct. 1997 and found some points to be improved. In this paper, we report some problems we actually faced with and then propose a new design we have developed to overcome these problems.

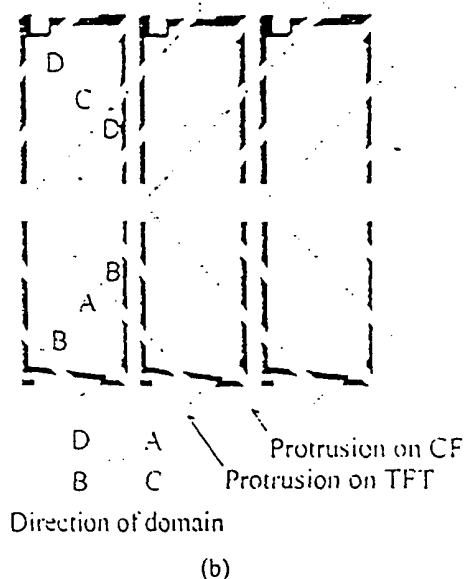
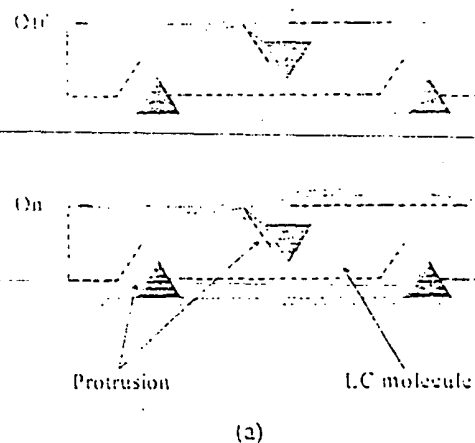


Fig1.(a):Basic concept of the MVA. The direction of the vertically aligned LC molecules are determined by the protrusions on the TFT and CF substrates.
(b)Actual protrusion design on the TFT and CF substrates to realize four different tilted directions for wide viewing angle.

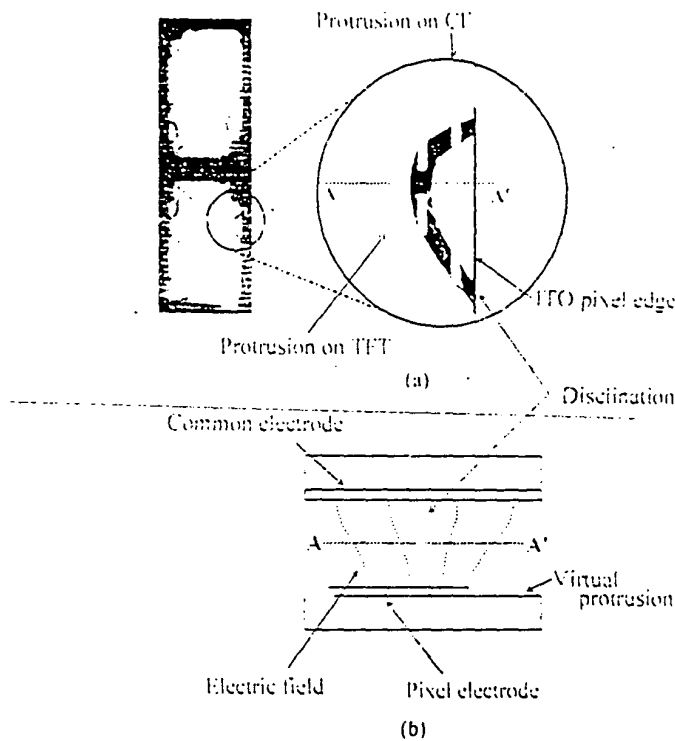


Fig2. (a): Photograph of the four domain MVA pixel and schematic illustration where the disclination appears.

(b): Schematic illustration of the cross section of A-A' in Fig.2(a). ITO pixel edge acts as a virtual protrusion and results in the formation of undesirable disclination in the pixel.

Transmittance improvement

As illustrated in Fig.1, we are using zigzag protrusion patterns to produce four domains in the pixel. The photograph of the actual pixel when the voltage is applied (white state) is shown in Fig.2. The big disclination lines are seen at specific position near the pixel edge. This results in the reduced transmittance of the MVA panels. To increase the transmittance, these disclination lines must be removed.

The existence of the disclination lines indicates that the tilted directions of the LC molecules near the pixel edge are different. We measured the azimuthal directions of the LC molecules and the results are also illustrated in Fig. 2. The azimuthal directions are opposite way for domains divided by the disclination line and the cause can be estimated by the edge field effect of the ITO (3-5).

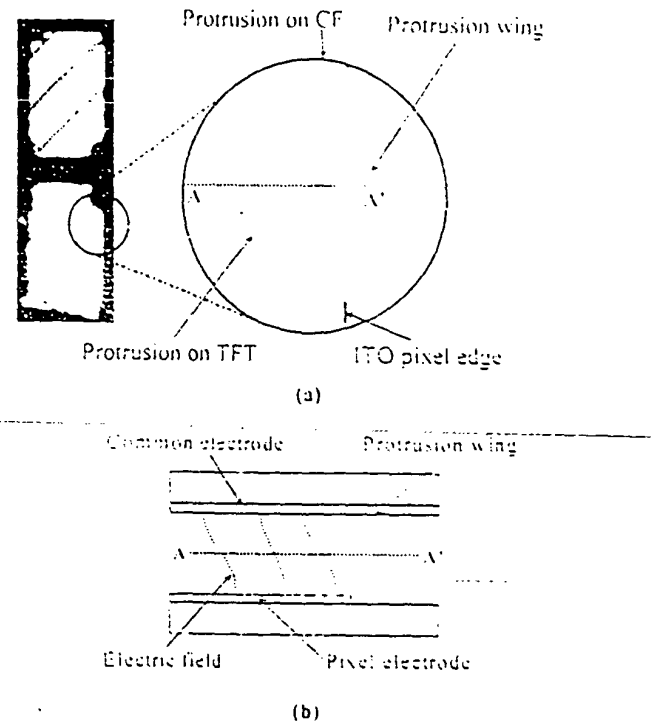


Fig3. (a): Photograph of the improved MVA pixel and schematic illustration of the arrangement of newly introduced protrusion wing to remove the disclination.

(b): Schematic illustration of the cross section of A-A' in Fig.3(a). The effect to control the tilted direction of the LC molecule of the newly introduced protrusion wing is greater than that of the ITO pixel edge effect in the conventional panel.

This situation is illustrated as a cross sectional view in Fig.2(b). Because the pixel edge acts almost the same as the protrusion due to distorted electric field, we have two (real and virtual) protrusions on the same substrate without protrusion on the counter electrode between them. Since the tilted directions determined by the protrusion and the edge field effect of the pixel ITO are different, the big disclination lines appear at the specific position near the ITO edge.

To remove this disclination line, we put an additional protrusion on the counter electrode which is just faced to the pixel edge as illustrated in Fig.3. The newly adopted protrusion is called "protrusion wing", and the ability to

control the tilted direction is much stronger than that of the edge field effect (virtual protrusion). Thus the undesirable disclination lines, the major cause of the reduction in transmittance, completely disappear as shown in the photograph in Fig.3(a). The transmittance improvement effect is measured to be 13% in typical.

Patterned ITO slit

As discussed in the previous section, the ITO edge acts as the virtual protrusion although the ability to tilt the LC molecule is weaker than that of the real protrusion. Therefore, we tried to replace the protrusions on the TFT substrate to the patterned ITO slit in order to simplify the production step. Fig. 4 shows the schematic illustration of the developed structure. Basically this concept is al-

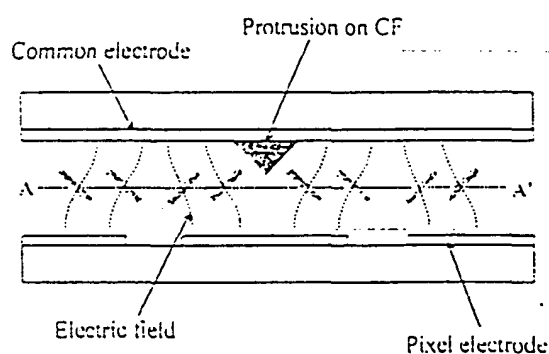


Fig. 4. Structure of the combination of slit and protrusions

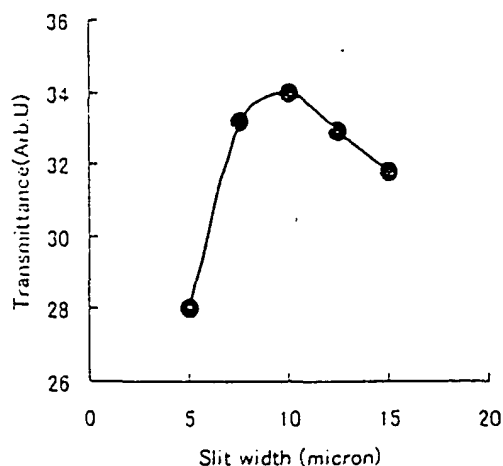


Fig. 5. Transmittance vs slit width

most the same as already reported by Lien et al (5). We intentionally made slit patterns in the pixel in order to keep the same viewing angle characteristics and the response time as the previous panel. The disadvantage by this design change is thought to be the transmittance reduction due to reduced effective areas of the pixel. Because the effective area is dependent on the slit width, we measured the relationship between the transmittance and slit width.

Fig.5 shows the relationship between slit width and transmittance of the MVA panels. When the slit width is less than 7 μm , the transmittance reduces steeply due to weakened edge field or vanished virtual protrusion effect. The maximum transmittance is obtained around 10 μm . The transmittance is considerably decreased with further increment of the slit width due to decreased effective areas in the pixel. Thus the enough process margin can be obtained around 10 μm . The realized transmittance is al-

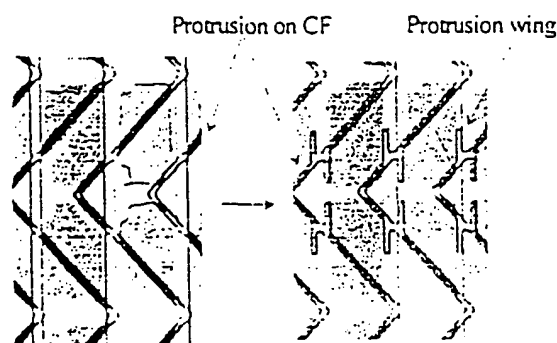


Fig 6-(a)

Fig 6-(b)

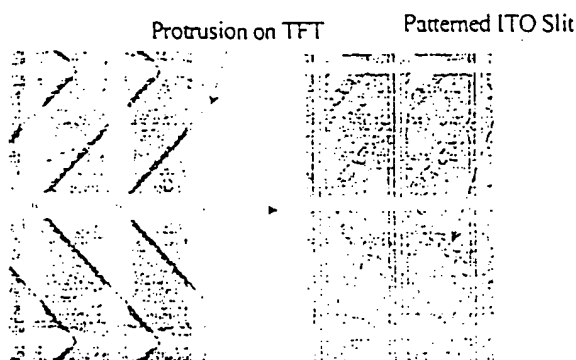


Fig 6-(c)

Fig 6-(d)

- Fig 6-(a) Conventional design of CF substrate
 (b) Present design of CF substrate
 (c) Conventional design of TFT substrate
 (d) Present design of TFT substrate

most the same as the previous MVA panel using protrusions of 5 μm which is determined by the resolution of photolithography line. Fig. 6 shows difference between conventional and the developed patterns both for CF and TFT substrates.

By eliminating the protrusion step, any additional process is not required for the TFT substrate. This is very helpful to reduce the production cost of the MVA-TFT. In addition to this, the ITO slit structure has an advantage of increasing the contrast of the MVA panels. Since the contrast is mainly determined by the leakage light through the tilted LC molecules region when the voltage is not applied, that is the slope region of the protrusions, the replacement of the protrusion to the ITO slit reduces almost half of the leakage light. This results in the huge contrast improvement from 300:1 to 500:1 in typical. The switching speed that might be influenced by this design change was measured, but no difference in the switching speed has been observed between conventional and present panels.

Aperture ratio

Because the MVA panels are operated by Normally-Black mode, we do not need to put overlapping of Black Matrix areas at the marginal region of the pixel electrodes. This overlapping area is essential for normal TN display operated by Normally White mode to avoid contrast reduction due to leakage light by alignment errors between CF and TFT patterns. By removing these areas and redesign whole parameters concerning TFT matrix array, we increased aperture ratio from 57.9% to 67.6%. By combining the transmittance improvement by the disappearance of the disclination lines discussed above, total improvement of 32% in transmittance was achieved. This new design is very essential not only to improve the transmittance of the panel but also to improve a production yield due to the increased margin of the alignment errors.

Summary

The MVA-TFT LCD has been improved from view points of optical characteristics and production process. The detailed analysis of the LC alignment of the disclination lines gave the new design to vanish the disclination lines.

Table 1. Summary of improvements for 15" MVA-LCD

	Conventional	Present
Aperture ratio (%)	57.9	67.6
Transmittance (%)	3.4	4.5
Brightness (cd/m ²)	200	250
Contrast ratio	300:1	500:1
Process step for protrusion	3	1

This increased the transmittance considerably. Also, the replacement of the protrusions to the patterned ITO slits simplified the production process of the TFT substrate. No additional step is needed to prepare TFT substrate as compared with that for normal TN mode. This leads another advantage of the contrast improvement due to reduced light leakage from the slope region of the protrusions. Table 1 summarizes the improvement of our new MVA-TFT LCD. These improvements have already been adopted to commercial MVA-TFT LCDs.

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